ATTACHMENT B

THE BENEFITS OF REDUCING NITRATE CONTAMINATION IN PRIVATE DOMESTIC WELLS UNDER CAFO REGULATORY OPTIONS

U.S. Environmental Protection Agency
1200 Pennsylvania Ave., NW
Washington, DC 20460

January 8, 2001

CONTENTS

Chapter 5 Groundwater Valuation Studies

Chapter 6 Benefit Calculations

Appendices

Exhibits

ACKNOWLEDGMENTS AND DISCLAIMER

This report has been reviewed and approved for publication by the Engineering and Analysis Division, Office of Science and Technology. This report was prepared with the support of Stratus Consulting Inc. under the direction and review of the Office of Science and Technology.

The author thanks Stratus Consulting Inc. for their assistance and support in performing the underlying analyses supporting the conclusions described in this report. Particular thanks are given to Jeffrey K. Lazo, Robert S. Raucher, and Megan Harrod. Additional analysis and support was provided by Maurice Hall of CH2M Hill of Redding, California, and Don Waldman of the University of Colorado at Boulder.

EXECUTIVE SUMMARY

Concentrated animal feeding operations (CAFOs) can contaminate aquifers and thus impose health risks and welfare losses on those who rely on groundwater for drinking water or other uses. Of particular concern are nitrogen and other animal waste-related contaminants (which come from manure and liquid wastes) that leach through soils and ultimately reach groundwater. Nitrogen loadings convert to elevated nitrate concentrations at household and public water system wells, and elevated nitrate levels in turn pose a risk to human health.

The federal health-based National Primary Drinking Water Standard for nitrate is 10 mg/L. This Maximum Contaminant Level (MCL) applies to all community water supply systems, but not to households that rely on private wells. As a result, households served by private wells are at risk to exposure to nitrate concentrations above 10 mg/L, which EPA considers unsafe for sensitive subpopulations (e.g., infants). Nitrate above concentrations of 10 mg/L can cause methemoglobinemia ("blue baby syndrome") in bottle-fed infants (National Research Council, 1997), which causes a blue-gray skin color, irritableness or lethargy, and potentially long-term developmental or neurological effects. Generally, once nitrate intake levels are reduced, symptoms abate. If the condition is untreated, however, methemoglobinemia can be fatal. No other health impacts are consistently attributed to elevated nitrate concentrations in drinking water; however, other health effects are suspected.

The most recent U.S. Census data show that approximately 13.5 million households located in counties with animal feeding operations (AFOs) are served by domestic wells. According to the nationwide USGS Retrospective Database (1996) the concentration of nitrate in 9.7% of domestic wells in the U.S. exceeds the 10 mg/L threshold. Thus, EPA estimates that approximately 1.3 million households in counties with AFOs are served by domestic wells with nitrate concentrations above 10 mg/L.

EPA's proposed revisions to the National Pollutant Discharge Elimination System (NPDES) regulation and effluent guidelines would affect the number and type of facilities subject to regulation as CAFOs, and would also introduce new requirements governing the land application of manure. As a result, EPA anticipates that its regulatory proposal will reduce nitrate levels in household wells. In light of clear empirical evidence from the economics literature that households are willing to pay to reduce nitrate concentrations in their water supplies — especially to reduce concentrations from above the MCL to below the MCL — the anticipated improvement in the quality of water drawn from private domestic wells represents a clear economic benefit. This report estimates these benefits for each of the eight regulatory scenarios evaluated.

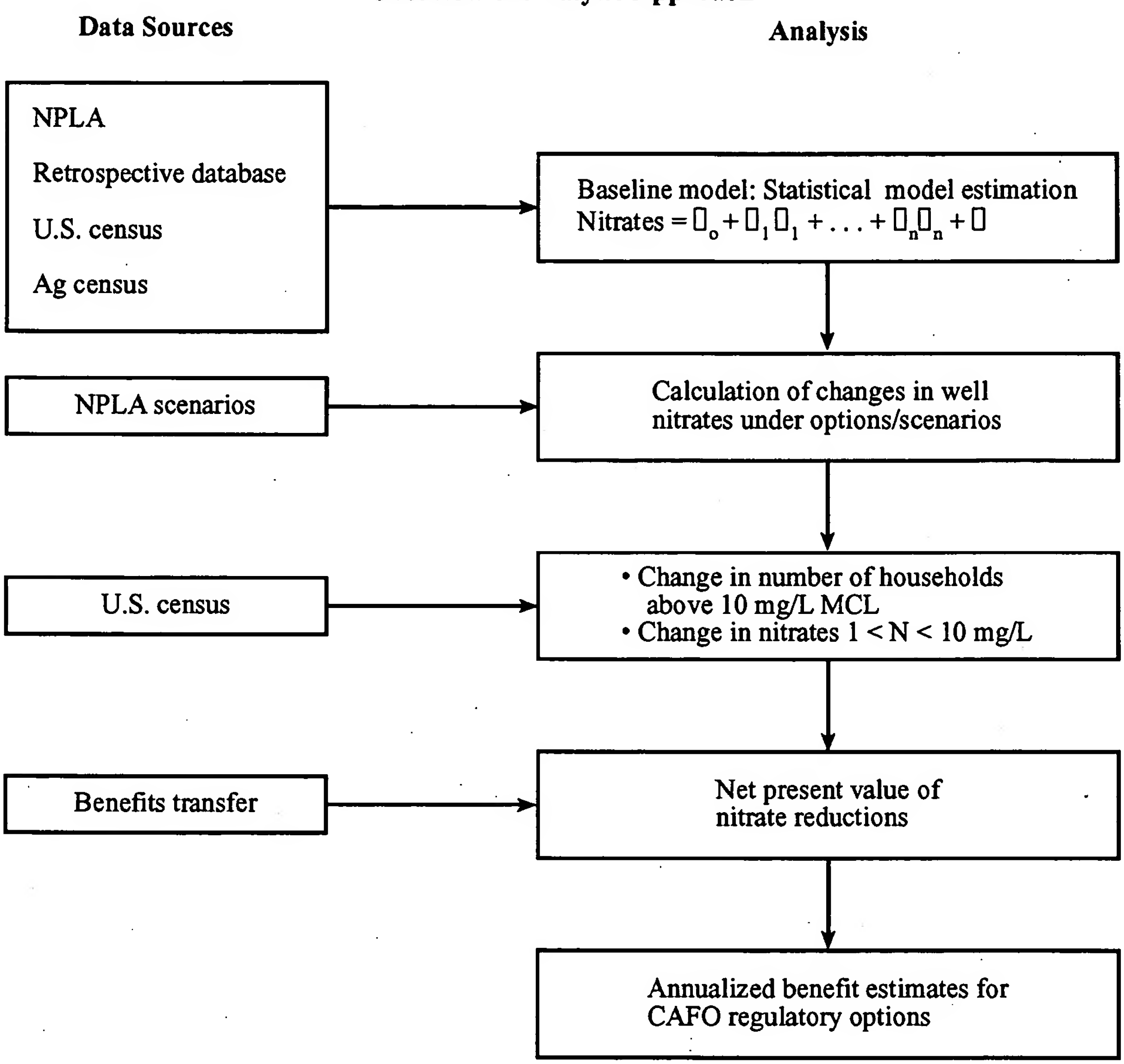
Exhibit S-1 provides an overview of the approach to estimating the benefits of well nitrate reductions. The analysis begins by developing a statistical model of the relationship between nitrate concentrations in private domestic wells and a number of variables found to affect nitrate levels, including nitrogen loadings from AFOs. It then applies this model, in combination with the projected change in nitrogen loadings from CAFOs under each regulatory scenario, to characterize the distribution of expected changes in well nitrate concentrations. Next, the analysis applies this distribution to the number of households served by private domestic wells to calculate (1) the increase in the number of households served by wells with nitrate concentrations that are below the MCL and (2) the marginal change in nitrate concentrations for households currently served by wells that are below the MCL. Finally, the analysis employs estimates of households' values for reducing well nitrate concentrations to develop a profile of the economic benefits of anticipated improvements in well water quality.

Regression Analysis: Baseline Model

The approach begins with the use of regression analysis to develop a model characterizing the empirical relationship between well nitrate concentrations and a number of variables that may affect nitrate levels, including nitrogen loadings from AFOs. The primary purpose of the model is to estimate the effects of nitrogen loadings from CAFOs on domestic well nitrate concentrations while *controlling for* other sources of nitrogen and well characteristics that could affect this relationship. Controlling for other sources of nitrogen in particular ensures that decreases in nitrogen loadings from CAFOs as a result of regulatory activities do not lead to overestimates of the resultant impact on well nitrate concentrations.

The variables included in the model are based on a review of hydrogeological studies that have observed statistical relationships between groundwater nitrate concentrations and various other hydrogeological and land use factors. The dependent variable, domestic well nitrate concentrations, was obtained from the USGS Retrospective Database. Data were compiled for 2,928 observations in 364 counties. The regression model includes variables characterizing nitrogen loadings from animal feeding operations [data obtained from the National Pollution Loadings Analysis (NPLA)], agricultural fertilizers and atmospheric deposition (data obtained from the USGS Retrospective Database), and septic systems (data obtained from the 1990 U.S. Census). The model also includes variables describing well depth, soil type, and land use characteristics around the well (data obtained from the USGS Retrospective Database).

Exhibit S-1
Overview of Analytic Approach



Calculation of Changes in Well Nitrates

After estimating the regression model using baseline loading information, the model was used to estimate expected values for well nitrate concentrations, both for baseline and for each of the eight alternative regulatory scenarios. The calculation of expected values under each scenario employed data on AFO nitrogen loadings obtained from the NPLA; these loadings vary across the regulatory scenarios, reflecting different manure application rates, manure management practices, and other factors. To examine the impact of alternate regulatory scenarios on well nitrate concentrations, the AFO loadings variable is the only independent variable that changes value; the values for all other variables are held constant. Exhibit S-2 shows the reductions nationally in total nitrogen loadings from CAFOs under the different regulatory options/scenarios derived from the NPLA for the 2,504 counties in the NPLA indicated as having CAFOs.

Exhibit S-2
Nitrogen Loadings from CAFOs: Mean, Total, and Percent Reduction from Baseline (2,504 counties)

Option/Scenario	Mean (pounds per county)	Total (pounds nitrogen)	Percent Reduction from Baseline
Baseline	609,553	1,526,322,559	not applicable
Option 1 — Scenario 1	317,572	795,201,054	47.9
Option 1 — Scenario 2/3	294,320	736,978,193	51.7
Option 1 — Scenario 4a	221,454	554,522,671	63.7
Option 1 — Scenario 4b	221,454	554,522,671	63.7
Option 2 — Scenario 1	280,802	703,130,686	53.9
Option 2 — Scenario 2/3*	254,556	637,410,305	58.2
Option 2 — scenario 4a*	174,807	437,718,632	71.3
Option 2 — Scenario 4b	174,807	437,718,632	71.3

* Proposed scenarios.
Source: Calculations based on NPLA (TetraTech, 2000).

Discrete Changes from above the MCL to below the MCL

As noted above, under the baseline scenario, it is estimated that approximately 1.3 million households in counties with AFOs are served by domestic wells with nitrate concentrations above 10 mg/L. To estimate the impact of alternative CAFO standards on the number of wells that would exceed the nitrate MCL, the mean percentage reduction in nitrate concentrations predicted under each regulatory scenario was applied to the observed nitrate concentration values that the USGS Retrospective Database reports.

Based on the resulting values, the percentage reduction in the number of wells with nitrate concentrations exceeding 10 mg/L was calculated. These values were then applied to the baseline estimate of the number of households in counties with AFOs that are served by domestic wells with nitrate concentrations above 10 mg/L. Based on this analysis, it is estimated that the regulatory scenarios evaluated would bring between 150,000 and 166,000 households under the 10 mg/L nitrate threshold. Exhibit S-3 shows the number of households expected to have well nitrate concentrations reduced from above the MCL to below the MCL for each of the options/ scenarios.

Exhibit S-3
Expected Reductions in Number of Households with Well Nitrate Concentrations above 10 mg/L and in Total Nitrates under 10 mg/L

Scenario	Reduction in Number of Households above the MCL	Total Expected National Nitrate Reduction (mg/L)[a]
Option 1 — Scenario 1	152,204	961,741
Option 1 — Scenario 2/3	152,204	1,007,611
Option 1 — Scenario 4a	161,384	1,186,423
Option 1 — Scenario 4b	161,384	1,186,423
Option 2 — Scenario 1	161,384	1,103,166
Option 2 — Scenario 2/3*	161,384	1,159,907
Option 2 — Scenario 4a*	165,974	1,374,990
Option 2 — Scenario 4b	165,974	1,374,990

a. For wells at or below the MCL at baseline and above 1 mg/L.
* Proposed scenarios.

Incremental Changes below the MCL

Households currently served by wells with nitrate concentrations below the 10 mg/L level may also benefit from marginal reductions in nitrate concentrations. For purposes of this analysis, it is assumed that such incremental benefits would be realized only for wells with baseline nitrate concentrations between 1 and 10 mg/L; presumably, an individual would not benefit if nitrate concentrations were reduced to below background levels, which are assumed to be 1 mg/L. Marginal reductions in nitrate concentrations for wells that remain above the MCL are not calculated because we do not have reliable value estimates to apply to these changes. We also have not calculated values for marginal changes below the MCL for households that are above the MCL as baseline and below the MCL after new regulations. These values are potentially already captured by benefit estimates used in the benefits transfer for wells achieving safe levels. This analysis thus takes a conservative approach to benefits estimation.

For each regulatory scenario, the mean and median reduction in nitrate concentrations for wells with baseline values between 1 and 10 mg/L was estimated. The last column of Exhibit S-3 indicates the aggregate reduction in mg/L expected nationally for wells with nitrate levels below the MCL before new regulations. Approximately 600,000 households would benefit from these marginal reductions.

Valuation of Predicted Reductions in Well Nitrate Concentrations

The benefit valuation analysis relies on a benefits transfer approach to value predicted reductions in well nitrate concentrations. Three general steps were used to identify and apply values for benefits transfer. First, a literature search identified potentially applicable primary studies. Second, we evaluated the validity and reliability of the studies identified. Primary evaluation criteria included the applicability and quality of the original study, each evaluated on multiple criteria such as sample size, response rates, significance of findings in statistical analysis, etc. And, third, values for application to CAFO impacts were selected and adjusted. Through the review and evaluation of the relevant literature, three studies were selected to provide the primary values used for the benefit transfer:

- Poe and Bishop (1992): per household values for changes in well nitrate concentrations from above the MCL to below the MCL.
- Crutchfield et al. (1997): values marginal changes in nitrate concentrations below the MCL.
- De Zoysa and (1995): values marginal changes in nitrate concentrations below the MCL.

The Consumer Price Index (CPI) was used to convert the annual mean household willingness-to-pay values obtained from these studies to 1999 dollars. Exhibit S-4 shows the point value estimates used for benefits transfer.

Exhibit S-4
Willingness-to-Pay Values Applied to Benefits Transfer

Study	Value	1999$
Poe and Bishop	Annual WTP per household for reducing nitrates from above the MCL to the MCL	448.00
Average of Crutchfield et al. and De Zoysa	Annual WTP per mg/L between 10 mg/L and 1 mg/L	1.97

Total Annual Benefits

Based on the benefit estimates from Exhibit S-4 and the changes in well nitrates under the potential regulatory options/scenarios indicated in Exhibit S-3, Exhibit S-5 indicates the estimated total annual (undiscounted) benefits. These values are then adjusted for the timing of the reductions in well nitrates and discounted over the time frame of the analysis.

Exhibit S-5
Undiscounted Annual Values under CAFO Regulatory Scenarios (1999$)

Scenario	Total WTP for Discrete Reduction to MCL	Total WTP for Marginal Changes below 10 mg/L	Total
Option 1 Scenario 1	68,187,392	1,894,630	70,082,022
Option 1 Scenario 2/3	68,187,392	1,984,994	70,172,386
Option 1 Scenario 4b	72,300,032	2,337,253	74,637,285
Option 1 Scenario 4a	72,300,032	2,337,253	74,637,285
Option 2 Scenario 1	72,300,032	2,173,237	74,473,269
Option 2 Scenario 2/3*	72,300,032	2,285,017	74,585,049
Option 2 Scenario 4a*	74,356,352	2,708,730	77,065,082
Option 2 Scenario 4b	74,356,352	2,708,730	77,065,082

* Proposed scenarios.

Timing of Benefits

It is estimated that approximately 75% of affected wells would realize the new predicted nitrate levels within 20 years (Hall, 1996). Assuming that the number of wells achieving these levels increases linearly over time, this translates to approximately 3.7% of wells achieving new steady state conditions each year. This analysis assumes this rate, so that all affected wells reach the new levels in 27 years.

Discounting

Three discount rates are used to calculate the net present value of the benefits from reductions in domestic well nitrate levels: 3%, 5%, and 7%.

Annualized Benefit Estimates

Because the benefit flows are uneven over time, the annualized values are presented. The annualized present value represents the constant level of benefits that would yield the same

discounted present value, using the same rate of discount, as the uneven flow of benefits. Exhibit S-6 presents the annualized benefit estimates for the total annual benefits shown in Exhibit S-5. For instance, for Option 2- Scenario 4a, using the 27 year timepath and a 3% discount rate, the present value of benefits would be $1,662.32 million. As shown in Exhibit S-6, a constant benefit flow of $38.4 million discounted at 3% would generate $1,662.32 million in total present value of benefits, also discounted at 3%.

Exhibit S-6
Annualized Present Value of Option/Scenarios Using Different Rates of Discount
(millions 1999$)

Scenario	3% Annualized Value	5% Annualized Value	7% Annualized Value
Option 1 Scenario 1	46.37	37.77	31.07
Option 1 Scenario 2/3	46.43	37.82	31.11
Option 1 Scenario 4b	49.39	40.23	33.09
Option 1 Scenario 4a	49.39	40.23	33.09
Option 2 Scenario 1	49.28	40.14	33.02
Option 2 Scenario 2/3*	49.35	40.20	33.07
Option 2 Scenario 4a*	50.99	41.54	34.17
Option 2 Scenario 4b	50.99	41.54	34.17

* Proposed scenarios.

CHAPTER 1
INTRODUCTION AND OBJECTIVES

The U.S. Environmental Protection Agency (EPA) is revising and updating the two primary regulations that ensure that manure, wastewater, and other process waters generated by confined animal feedlot operations (CAFOs) do not impair water quality. The proposed regulatory changes affect the existing National Pollutant Discharge Elimination System (NPDES) provisions that define and establish permit requirements for CAFOs, and the existing effluent limitations guidelines (ELGs) for feedlots, which establish the technology-based effluent discharge standard that applies to regulated CAFOs. The existing regulations were promulgated in the 1970s, and EPA is revising the regulations to address changes in the animal industry sectors over the last 25 years, to clarify and improve implementation of CAFO requirements.

CAFOs can contaminate groundwater and thus cause health risks and welfare losses to people relying on groundwater for their potable supplies or for other uses. Of particular concern are nitrogen and other animal waste-related contaminants (which come from manure and liquid wastes) that leach through the soils and the unsaturated zone and ultimately reach groundwater. Nitrogen loadings convert to elevated nitrate concentrations at household and community system wells, and elevated nitrate levels in turn pose a risk to human health. The proposed regulation will generate benefits by reducing nitrate levels in household wells, and there is clear empirical evidence from the economics literature indicating that households are willing to pay to reduce nitrate concentrations in their water supplies.

The federal health-based National Primary Drinking Water Standard for nitrate is 10 mg/L, and this Maximum Contaminant Level (MCL) applies to all Community Water Supply systems. Households relying on private wells are not subject to the federal MCL for nitrate; however, levels above 10 mg/L are considered unsafe for sensitive subpopulations (e.g., infants). Nitrate above concentrations of 10 mg/L can cause methemoglobinemia ("blue baby syndrome") in bottle-fed infants (National Research Council, 1997), which causes a blue-gray skin color, irritableness or lethargy, and potentially long-term developmental or neurological effects. Generally, once nitrate intake levels are reduced, symptoms abate. If the condition is untreated, however, methemoglobinemia can be fatal. No other health impacts are consistently attributed to elevated nitrate concentrations in drinking water.

U.S. Census data show that there are currently approximately 13.5 million households with domestic wells located in counties with animal feedlot operations. CAFOs present a potential contaminant source to groundwater, particularly via nitrogen leached from manure. Manure from these operations is generally managed by either storing it in a waste lagoon, where waste has the potential to leak through the lining or overflow onto the surrounding ground and leach nitrogen

into the groundwater, or by spreading it on surrounding farm fields, where, depending on the rate and timing of the applications, the soil hydrology, and precipitation, nitrate may leach into the groundwater. Nitrate is of particular concern because it leaches easily into groundwater, and is one of the most frequently found groundwater contaminants (Lichtenburg and Shapiro, 1997).

CAFOs are currently covered by existing effluent guidelines at 40 CFR Part 412 and permit regulations at 40 CFR Part 122. The effluent guidelines regulations, which require the largest CAFOs to achieve zero discharge of waste to surface waters except under extreme storm events, have not been sufficient to resolve water quality impairment from feedlot operations. Under the current permit regulations, a CAFO is a facility in one of the following three categories:

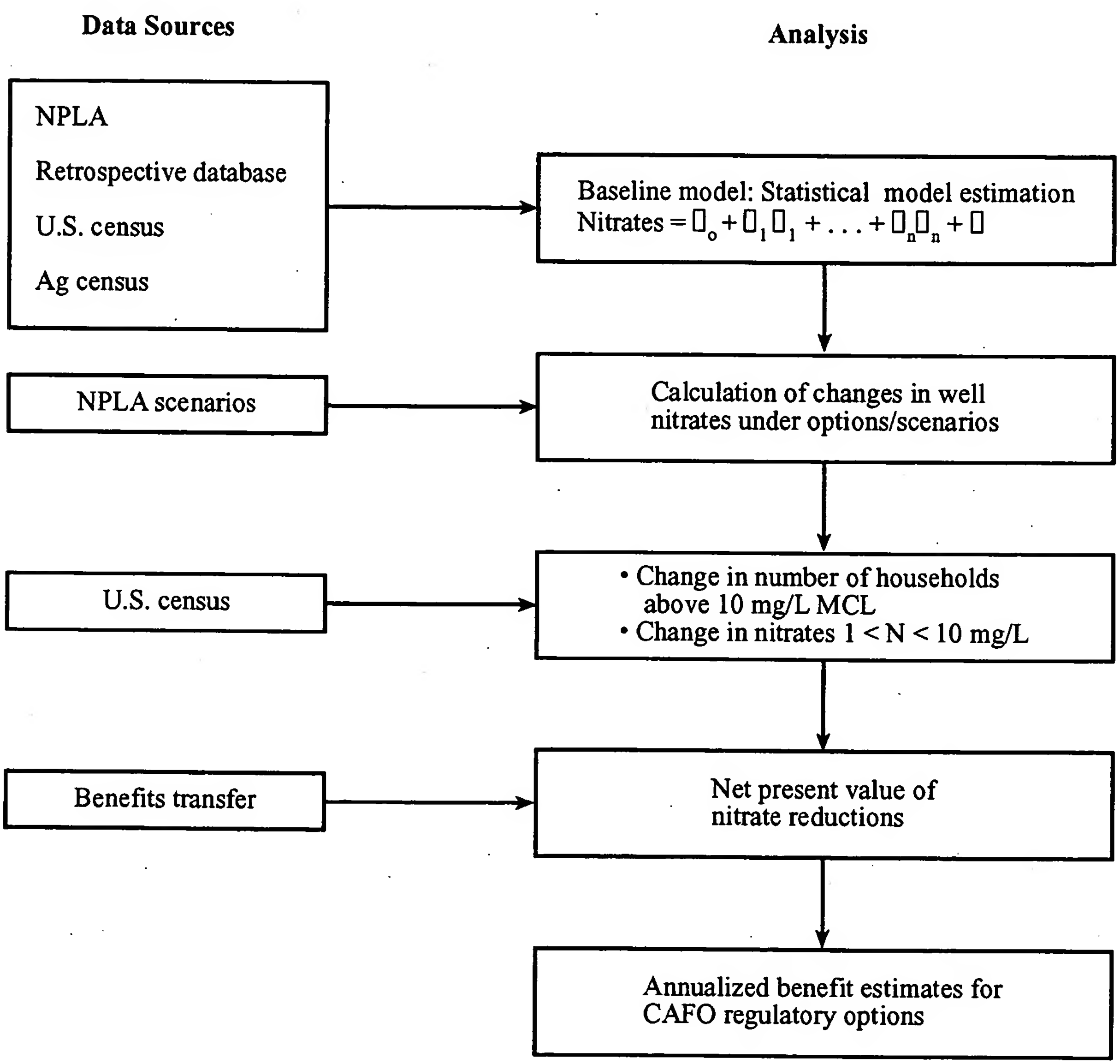
- more than 1,000 animal units confined at the facility
- 301-1,000 animal units confined and the facility also meets one of the specific criteria addressing the method of discharge [40 CFR Part 122 Appendix B]
- designated as a CAFO on a case-by-case basis if the NPDES-authorized permitting authority determines that it is a significant contributor of pollution to waters of the United States [40 CFR part 122.23(c)].

This report estimates benefits for national reductions in nitrate concentrations in private domestic wells achieved by changing regulations for effluents from CAFOs. Benefits achieved via this regulation for public and surface water systems are considered elsewhere in this regulatory analysis. The proposed regulatory options include different criteria for the definition of a CAFO, therefore changing the number of operations that will have to comply with the proposed regulations. They also include requirements for the quantity and rate of land application of manure, as well as water quality reporting. The current regulations address only controls at the feedlot; land application of manure is not addressed. This analysis evaluates the potential benefits from eight regulatory scenarios.

1.1 OVERVIEW OF BENEFIT ASSESSMENT METHOD

The assessment of benefits of well nitrate reductions from CAFO regulations followed a multistep process outlined in Exhibit 1-1.

Exhibit 1-1
Analysis Plan and Data Sources



To estimate the benefits achieved by reducing nitrogen loadings from animal manure and thus improving groundwater quality, we first established baseline water quality under current loadings and current regulations using available data on nitrate concentrations in individual wells. These data, described further in Chapter 2, were obtained from a national database of groundwater quality. We then used these baseline data for nitrate concentrations and data on current nitrogen loadings by county to model the relationship between nitrate concentrations and nitrogen loadings. Our model also included significant explanatory variables such as well depth and soil hydrological characteristics that were identified from a literature survey. We then applied the parameter estimates generated from this model to projected loadings under each regulatory scenario to estimate changes in nitrate concentrations in the wells for each regulatory option.

From these data we established the percentage of wells above the MCL (10 mg/L) under each scenario, as well as the nitrate reduction for wells that were already below 10 mg/L at baseline. We then extrapolated these values to the total number of household units on private wells in the country to estimate the number of households that would have nitrate concentrations reduced from above the MCL to below the MCL, as well as how many households that were already below the MCL at baseline and would have further water quality improvements under the regulatory scenarios.

After reviewing studies that estimated household-level monetary benefits of improving water quality through reduced nitrate concentrations, we established a range of values for both reducing nitrate from above the MCL to below the MCL and reducing nitrate concentrations in wells that were already below the MCL at baseline. Using benefits transfer methods, we then estimated the total monetary benefits that could be achieved under each scenario, based on the number of households brought from above the MCL to below the MCL and the number of households that achieved water quality improvements below the MCL.

Monetary benefits were estimated annually over a 100 year time period to capture the time path until well nitrates would achieve a steady state following implementation of each regulatory option. We assumed that it would take 27 years to achieve the steady state. Discounting was applied to determine net present values and these were then annualized to derive a benefit estimate to be used in comparison to annualized cost estimates. Sensitivity analysis was performed to examine how annualized benefit estimates change using different discount rates, years until clean, and per household benefit values.

1.2 REPORT STRUCTURE

Chapter 2 discusses the choice of variables to include in modeling the relationship between loadings from CAFOs and well nitrate concentrations, and data sources used in the analysis. This chapter also includes information on the methods used to calculate loadings for each scenario and descriptions of each scenario.

Chapter 3 discusses the model of the relationship between nitrogen loadings and well nitrate concentrations. Statistical analyses and parameter estimates from analyses based on this model, assuming a gamma distribution, are included. Chapter 3 also discusses the results from running the parameter estimates through each of the regulatory scenarios with different loadings and the subsequent changes in well nitrate concentrations.

Chapter 4 discusses the benefits transfer method in detail.

Chapter 5 discusses the groundwater valuation studies used in this analysis, including a ranking of their relevance to this study, the various methods that each used to estimate benefits, and their respective values for reducing groundwater contamination.

Chapter 6 provides a summary of benefit estimates using the different assumptions regarding which approach to apply for extrapolating from the model to the population, the time until a new steady state is achieved, and the discount rate used. Omissions, biases, and uncertainties in the analysis are discussed here.

References are provided for both the nitrate modeling and benefits analysis portions of this report.

The appendices include information on nitrogen loading data sets, details of the statistical analyses of the nitrogen-nitrate relationship, and tables summarizing the literature used in the benefits transfer analysis.